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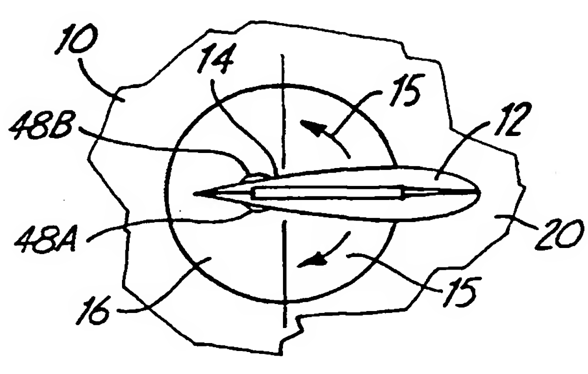
*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: INTEGRATED PROBE AND SENSOR SYSTEM




(57) Abstract: A flow aligned device (12, 66, 100, 122, 150, 176, 214, 234) comprises a probe or vane (12, 66, 100, 122, 150, 176, 214, 234) that will sense angle of attack of an aircraft (10, 74, 106, 124, 164, 180, 210, 231). The flow aligned device (12, 66, 100, 122, 150, 176, 214, 234) is mounted about an axis (14, 116, 130, 156, 200, 220, 240) that is generally perpendicular to an aircraft, and includes pressure sensing ports for sensing pitot pressure (40A, 70, 170, 230, 246) and static pressure (48A, 73, 114, 144, 172) right on the vane (12, 66, 100, 150, 176, 214, 234). The trailing edge (34, 84, 108, 136, 166, 186, 218, 238) of the vane is inclined in a forward direction outwardly from the aircraft body to permit items that may be sliding along the aircraft body from the rear toward the front (e.g. air-to-air refueling baskets) to slide past the vane (12, 66, 100, 122, 150, 176, 214, 234) without being hooked or caught.

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# INTERNATIONAL SEARCH REPORT

International Application No
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**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 G01P13/02 G01P5/165 B64D43/02 B64D39/00

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01P B64D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No |
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| Y | WO 99 61923 A (KOEHLER HEINZ GERHARD ;NORD MICRO ELEKTRONIK FEINMECH (DE); AEROPR) 2 December 1999 (1999-12-02) page 8, paragraph 5; figures 1,10,13,27,30 | 1-6,8-14 |
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| A | US 5 115 237 A (GREENE LEONARD M) 19 May 1992 (1992-05-19) the whole document | 10 |

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 12 October 2001 | 24/10/2001 |

| Name and mailing address of the ISA | Authorized officer |
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| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Pflugfelder, G |

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

Interna... al Application No
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| Patent document cited in search report | | Publication date | Patent family member(s) | | Publication date |
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(71) Applicant: ROSEMOUNT AEROSPACE INC. [US/US]; 14300 Judicial Road, Burnsville, MN 55306 (US).

(72) Inventors: GOLLY, Timothy, T.; 9409 178th West, Lakeville, MN 55044 (US). HOLM, Douglas, M.; 2215 Monroe Street N.E., Minneapolis, MN 55418 (US).

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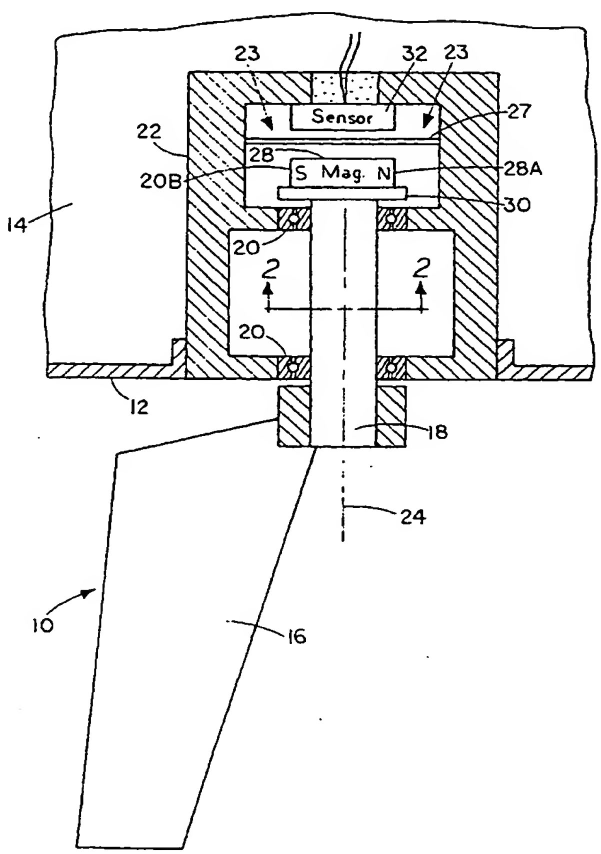
*[Continued on next page]*

(54) Title: MAGNETIC ANGLE OF ATTACK SENSOR




(57) Abstract: An angle of attack sensor (10) has a rotating vane (16) that is sensitive to airflow direction mounted on a shaft (18) that in turn is rotatably mounted on a housing (22). The housing (22) is supported on an aircraft (14), and includes a non contact magnetic sensing assembly (23) for sensing the rotation of the shaft (18) relative to the housing (22). The sensor assembly (23) includes a magnet (28) that mounts on the shaft (18), and a magnetoresistive (MR) sensor (32) that mounts on the housing (22) in a position so that as the shaft (18) rotates the magnetic field from the magnet (28) changes, and this change in magnetic field is sensed and provided as an indication of angle of attack change.

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# MAGNETIC ANGLE OF ATTACK SENSOR

## BACKGROUND OF THE INVENTION

The present invention relates to rotary angle of attack sensors used with non contact angle sensors, specifically magnetic field sensing devices, which can be used for determining the angle of rotation of a sensor that rotates as a function of angle of attack of an aircraft.

Vane type angle of attack sensors have been used for years and the physical structure of mounting is and can be the same in the present invention as has been used. Prior art sensors for sensing the angle of movement of the rotating vane have included potentiometers, angle resolvers, sychros and RVDT's.

The sychros, angle resolvers and RVDT's do not have contacting parts, but potentiometers do. One of the advantages of having non contact sensors is the ability to increase modular designs so that different configurations of sensor-vane interchanges can be made. Sychros, resolvers and RVDT's that are non contact rotating sensors are expensive, heavy and require substantial instrumentation to operate.

## SUMMARY OF THE INVENTION

The present invention relates to an angle of attack sensor utilizing a shaft that rotates about a mounting axis and includes a magnetic field sensor arrangement to determine rotation of the mounting shaft relative to a fixed reference. The magnetic sensor devices are arranged to sense the relative rotation of the shaft relative to a mount, and include magnets on one of the components, and a magnetic field sensitive device on the other of the components. The

magnets preferably will rotate with the shaft and the normal vane used, but the magnets can be stationary. The sensor which senses the changes in the magnetic field caused by shaft and vane rotation can be mounted in a fixed support for ease of receiving the output signal, but also can be mounted on the rotating vane. The fixed and moveable sections of the sensing device can be interchanged if desired.

Magnetic field sensors are quite low cost, and yet provide very high accuracy. Magnetoresistive (MR) type sensors, in particular, are accurate and sensitive to changes in position of magnets adjacent to the sensor.

The present design is simple, and few components are needed. The modularity of the magnetic sensor is a benefit in that the sensor can be used with many different configurations of mounting interfaces, vane geometries, and internal sensor assemblies. In other words, a family of angle of attack sensors can be created, by using the same rotation or angle sensor with different size vanes, and with different mountings.

The smaller size of the magnetic sensors permits the sensor systems to be retrofitted into existing aircraft applications as well. The savings in weight can be very effective.

There is a greatly reduced parts count since the sensors and circuits are prepackaged, so inventory is maintained easily. Magnetic sensors also can be calibrated easily.

The calibration can be carried out in wind tunnels, or in actual use i.e., when the sensor is attached to the air vehicle and compared with other

sensors. The calibration also can be accomplished by precision alignment of the sensor and magnet assemblies, in the manner used for existing potentiometers used with angle of attack sensors. Signal corrections and compensation needed can be made through suitable relatively simple circuitry. The correction or compensation is easily done with memory that stores the compensation factors and provides the factors to readout circuitry.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a top schematic sectional representation of an angle of attack sensor having a magnetic angle sensor made according to the present invention;

Figure 2 is a fragmentary sectional view taken on line 2--2 in Figure 1;

Figure 3 is a top schematic sectional view of a modified sensor according to the present invention; and

Figure 4 is a simplified block diagram of a circuit used with the sensor of the present invention.

## DETAILED DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENTS

An angle of attack sensor 10 is mounted on a fuselage 12 of an aircraft 14 in a location that permits fuselage vane 16 to rotate in response to changes of angle of attack of the aircraft 14.

The angle of attack sensor vane 16 is of conventional design, and it extends out into the airflow past the aircraft 14. The vane 16 is mounted on a shaft 18 that is rotatably mounted on bearings 20 supported in a housing 22 that is positioned on the interior of the aircraft 14.

The housing 22 is anchored to the aircraft in a suitable manner. The vane 16 rotates about the axis 24 of shaft 18 in response to angle of attack. The vane 16 can take any desired shape.

A magnetic based sensor assembly 23 is mounted in a chamber 25 of the housing 22 and includes a magnetic field sensor 32 and permanent magnet 28. When MR type sensors are used, the magnet 28 can be a ceramic or Alnico metal permanent magnet with a north pole 28A and a south pole 28B. The magnet 28 is mounted on a plate 30 that is fixed to an end of shaft 18 inside chamber 25 of the housing 22.

The housing 22 mounts one or more magnetic field or flux sensors 32. As shown one sensor is used. The sensor 32 is preferably a magnetoresistive sensor that provides an electrical signal that changes as the position of the magnetic poles 28A and 28B shift when the vane 16 and shaft 18 rotate. A barrier wall 27 made of material that is non magnetic and nonconductive and does not adversely affect sensing the magnetic field may be used to divide chamber 25 to environmentally isolate the sensor from the rotating parts. The magnetic field sensor 32 may be the preferred magnetoresistive sensor or other magnetic field or flux sensor that changes output as the magnet 28 shifts position about axis 24. For simpler, lower accuracy units, the magnetic flex sensor can be a Hall effect sensor.

An electrical signal is provided from sensor 32 which indicates the rotational portion of the magnet along a line that can be potted in the opening where it passes through a wall of the housing to keep the chamber 25 sealed. The signal from sensor 32 is

provided to suitable circuitry, shown in Figure 4. The magnetic field sensor 32 is excited from a power source 34 and provides an analog signal output that is a function of shaft rotation in either direction (positive for positive angle and negative for negative angle). Standard magnetoresistive sensor circuit chips are available, for example, MR displacement sensors are sold by Honeywell Inc. through their Solid State Electronics Center in Plymouth, Minnetonka. The sensor 32 output is provided to an analog to digital converter 36 for digital processing in a digital computer or processor 38 that can be provided in housing 22 or which can be a separate air data computer on board the aircraft. A memory 40, such as an EEPROM, is programmed with necessary correction or compensation factors, based on calibration tests of the angle of attack system including sensor 32.

The output of the sensor 32 may have a bias and be non linear, and the memory 40 can contain needed correction factors for correcting non linearities. The processor 38 will add the correction factors needed and will convert the signal from A/D converter 36 into a useful signal, such as degrees of rotation.

In addition to linearizing the output signal from sensor 32, it is also possible to make corrections caused by misadjustment of the sensor 32 and the magnet 28 during assembly. Because of the ability to electronically correct the output it is not necessary to precisely orient the sensor chip 32 and magnet 28 within the angle of attack unit during assembly. Offsets for local versus free stream angle of attack values for specific aircraft also can be

built-in to this calibration process to accommodate aircraft without central flight control computers, and to accommodate other special needs. The output of the angle of attack processor 38 can be left as a digital signal along line 41, to an output instrument or to avionics. Alternatively, a D/A converter 42, as shown in Figure 4, can be used to simulate a potentiometer, RVDT, resolver, or sychro for retrofit applications, as shown at 44. This makes the retrofit a self contained unit and does not require reworking other components that use the angle of attack signals. In other words the sensor output from sensor 32 is made compatible with the circuits of a retrofitted aircraft.

The processor 38 thus provides a corrected digital output to avionics or displays, or if desired, to a digital to analog converter 42 that provides an analog output.

Figure 3 illustrates a modified form of a sensor assembly 58. A shaft 60, which mounts the vane sensor used, such as vane 16, serves the same purpose as shaft 18 in Figure 1. Shaft 60 is an angle of attack vane mounting shaft and rotates when the vane rotates to indicate angle of attack.

A cup 62 is mounted on the inner or base end of shaft 60. The cup 62 has an open end 70, and a pair of diametrically opposed magnets 64 and 66 are mounted in the cup. The cup is made of non magnetic material. The north and south poles of the magnets are oriented as desired.

A sensor chip 68 having a magnetic flux sensor circuit is mounted on a base wall 65 of a housing 67 which is fixed to the wall of the aircraft.

The chip 68 extends into the cup open end 70. The shifting of shaft 60 changes the output of the magnetic flux sensor on the sensor chip 68. The circuit chip 68 provides an output using known circuitry, and it can be a MR sensor as mentioned. Because the sensor chip 32 or 68 and magnets 28, 64 and 66 are very small and only a few additional supporting components are required, magnetic output angle of attack units can be built much smaller and lighter than traditional angle of attack devices. The small size also allows the magnetic sensor to be used in wing-mounted angle of attack devices, test flight booms, and gimbaled probes where other types of prior art sensors have been too large or cumbersome to use. The power required to operate a magnetic sensor circuit is also much less than that required for other angle sensing devices.

The magnet (or sensor) can be mounted directly to the central shaft thereby eliminating any play or backlash as found in geared systems. Positioning the small magnet on the shaft eliminates additional gears, bearings, shafts, and other similar components and produces a very low inertia system which will allow for improved response times.

The sensor and its circuit does not mechanically contact the magnet so there is no wear to decrease accuracy over time. Internal friction in the system is also reduced because there are no additional bearings, gears, or wipers. Lower internal friction provides higher vane position accuracy and faster response time and will also allow the vane to function at lower airspeeds. Alternately, the lower friction will allow a smaller vane to be used at a similar

airspeed.

Non-magnetic materials can be positioned between the magnet and the sensor to provide a sealed environment for the sensor and the electronics to insure that accuracy is not degraded by contaminants and to extend the life of the product.

The sensor circuit in all forms of the invention does not influence the magnetic field produced by the magnet so multiple sensors can be used to provide redundancy or large ranges of angular travel if required. The sensor circuit is preferably designed to operate in saturation mode so the strength of the magnet, the temperature coefficient of the magnet, and the gap between the magnet and the sensor is unimportant within certain wide tolerances. Because the gap distance is not critical, sensors may be stacked on top of each other to save space. If necessary the magnet and sensor can be shielded from external magnetic sources by ferrite shields or other methods.

Reliability is greatly enhanced by the large reduction of mechanical parts and the high degree of redundancy that can be provided. Resistance to vibration and shock is improved because of the much lower complexity and low mass of the components compared to prior art angle of attack sensors. Because the sensor is non-contact there is no wear and the sensor circuit and related electronics can be placed in a sealed enclosure. In the event of a component failure the modular design for the magnetic sensor will allow for component assemblies to be swapped out quickly and easily.

This type of angular sensor could also be

used as a sensor for cone type angle of attack devices, control surface sensors, landing gear position sensors, throttle position sensors or other angular position, linear position or proximity measurements.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. An angle of attack sensor including a rotating portion that changes angular position as flow direction changes, and a non contact magnetic sensor for determining the rotation amount of the rotating portion from a reference position.

2. The angle of attack sensor of claim 1, wherein said rotating portion is mounted on a support; a magnet mounted on the support, and a magnetic field sensor mounted on the support for sensing changes in magnetic field as the magnet is rotated.

3. The angle of attack sensor of either claims 1 or 2, wherein said rotating portion comprises a shaft, a vane mounted to said shaft for sensing air flow and changing the angular position of the shaft as air flow direction changes relative to the vane.

4. The angle of attack sensor of claim 1 wherein said non-contact magnetic sensor comprises a permanent magnet mounted on one of the rotating portion and a stationary portion, and a magnetic field sensor mounted on the other of the rotating portion and the stationary portion.

5. The rotating angle of attack sensor of claim 1 including a housing, the rotating portion comprising a angle of attack sensing vane mounted on a shaft, said shaft being rotatably mounted in the housing, the non contact magnetic sensor comprising a permanent magnet mounted to rotate with said shaft, and a magnetic field sensor mounted on the housing adjacent

said magnet for sensing changes in the magnetic field caused by rotation of the magnet past the magnetic field sensor.

6. The rotating angle of attack sensor of claim 6 wherein said magnetic field sensor comprises one of a group consisting of a magnetoresistive sensor and a Hall effect sensor.

7. An angle of attack sensor comprising a shaft, a flow angle sensitive vane mounted on an outer end portion of the shaft and protruding into an air stream, a housing adapted to be mounted on an aircraft with the vane in an airstream adjacent the aircraft, said shaft being rotatably mounted on said housing about an axis, a magnetic field sensor and a magnetic field creating device, one of said sensor and said magnetic field creating device being mounted on the shaft, and the other of said sensor and magnetic field creating device being mounted on the housing.

8. The angle of attack sensor of claim 7 wherein said magnetic field creating device comprises a permanent magnet having spaced north and south magnetic poles, the magnet being mounted to rotate with said shaft whereby the magnetic field adjacent said magnet changes as the shaft rotates.

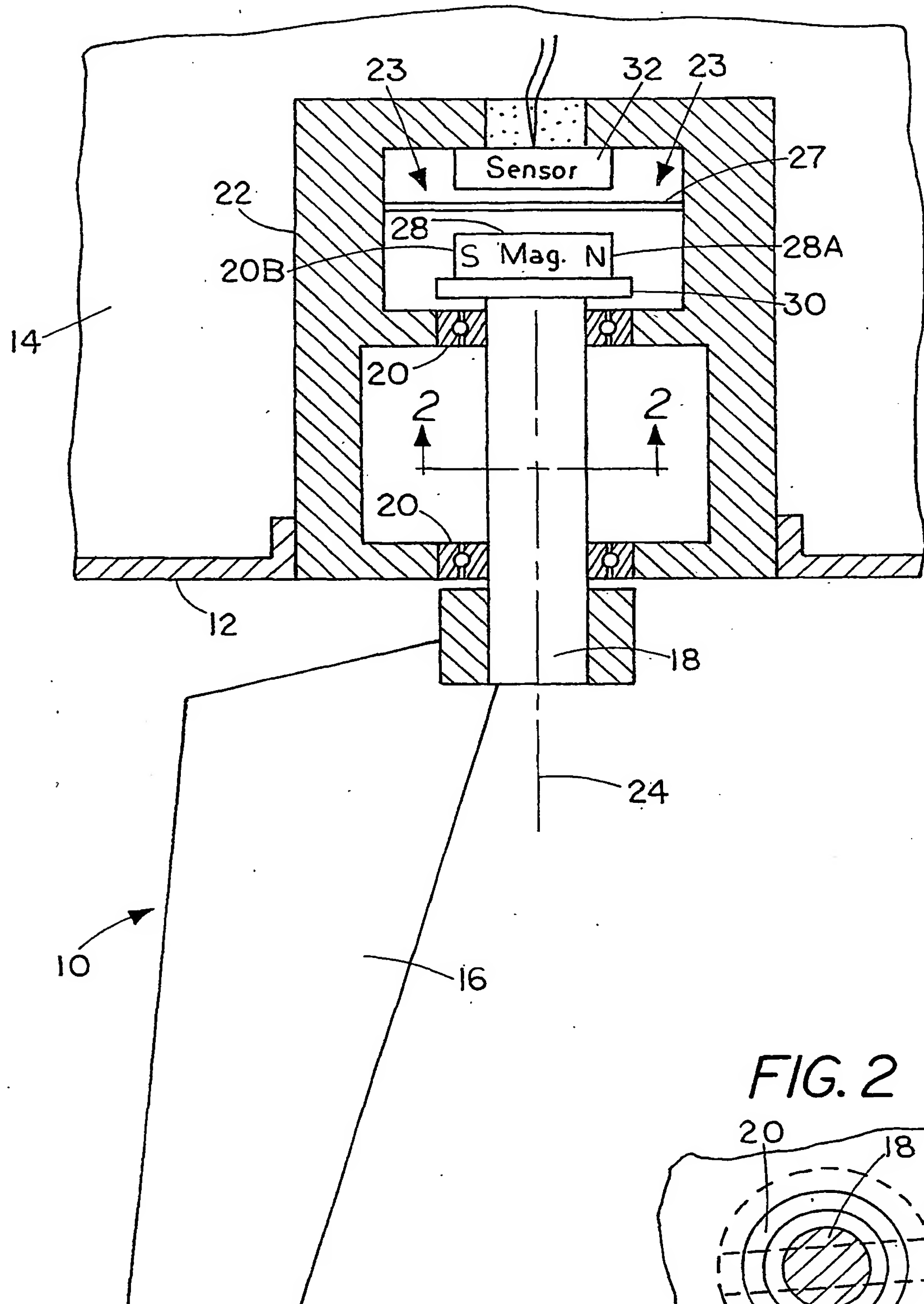
9. The angle of attack sensor of claim 8 wherein said magnetic field sensor is one of a group consisting of a magnetoresistive sensor and a Hall effect sensor.

10. The angle of attack sensor of claim 7, wherein the magnetic field creating device comprises a pair of magnets, and a magnet mounting housing mounted on said shaft and mounting the pair of magnets in position with the pair of magnets that are spaced apart from the axis of rotation of the shaft, one of the magnets having a north magnetic pole adjacent the sensor, and the other of the magnets having a south magnetic pole adjacent the sensor.

11. An angle of attack sensor comprising a shaft that rotates about an axis in response to changes of angle of attack of an aircraft, a permanent magnet mounted to rotate with said shaft to create a magnetic field, and a magnetoresistive sensor supported on a stationary portion of the angle of attack sensor and sensing changes in the magnetic field as the shaft rotates.

12. The angle of attack sensor of claim 11 wherein said shaft is mounted in a housing, said housing being adapted to be supported on an aircraft, and the housing including a sealed chamber for mounting said permanent magnet and said magnetic field sensor.

FIG. 1


23
32
23
Sensor
27
22
28
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28A
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16

FIG. 2

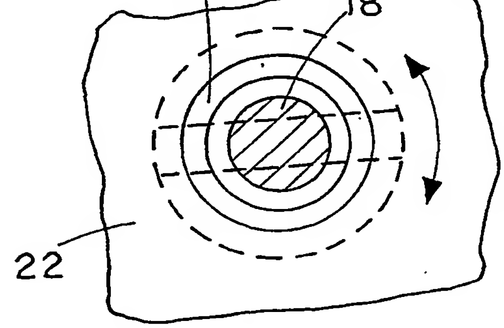
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FIG. 3

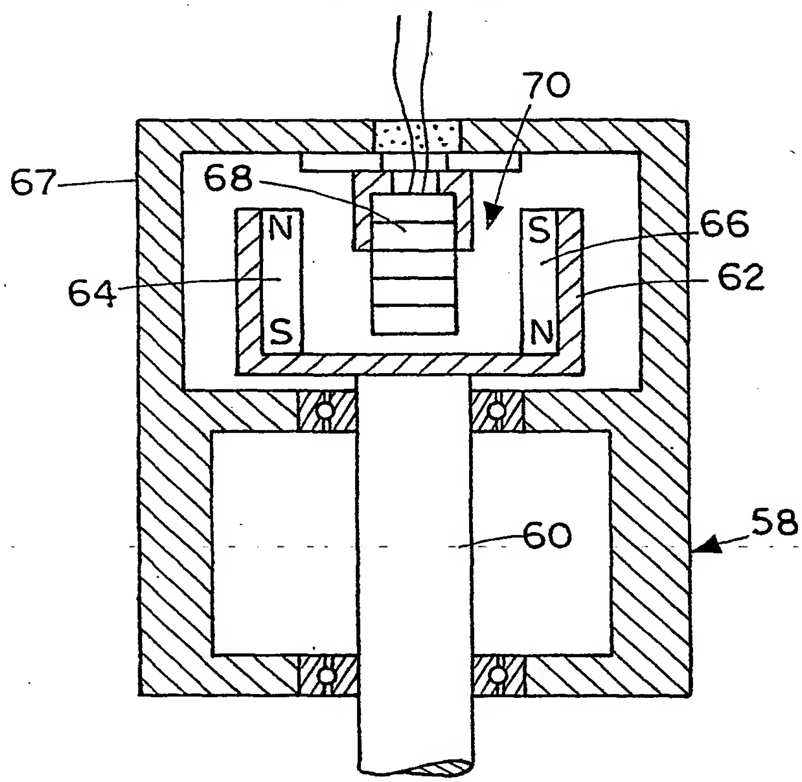
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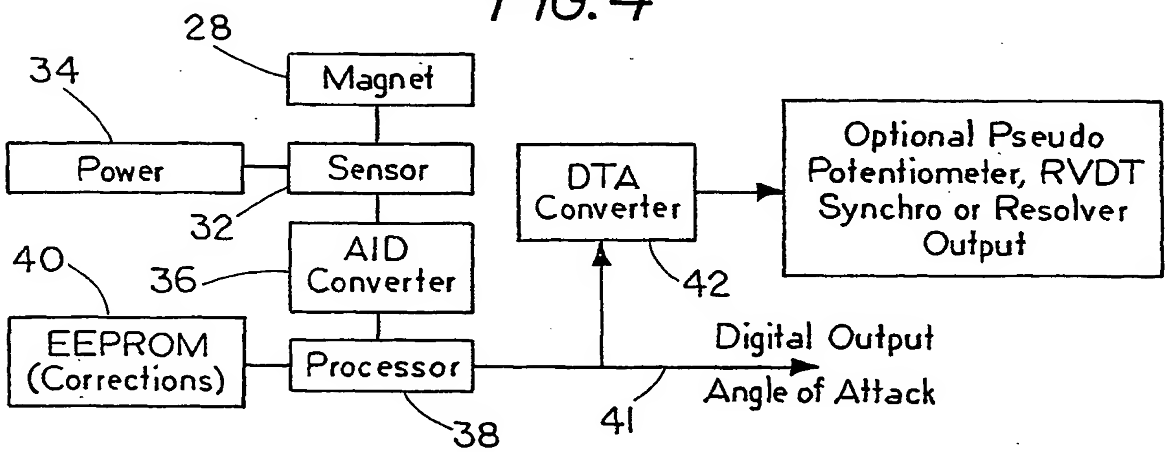
FIG. 4


28
Magnet
34
Power
Sensor
32
DTA Converter
Optional Pseudo Potentiometer, RVDT Synchro or Resolver Output
40
36
AID Converter
42
EEPROM (Corrections)
Processor
Digital Output
Angle of Attack
38
41

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(74) Agents: WESTMAN, Nickolas, E. et al.; Westman, Champlin & Kelly, P.A., Suite 1600 - International Centre, 900 Second Avenue South, Minneapolis, MN 55402-3319 (US).

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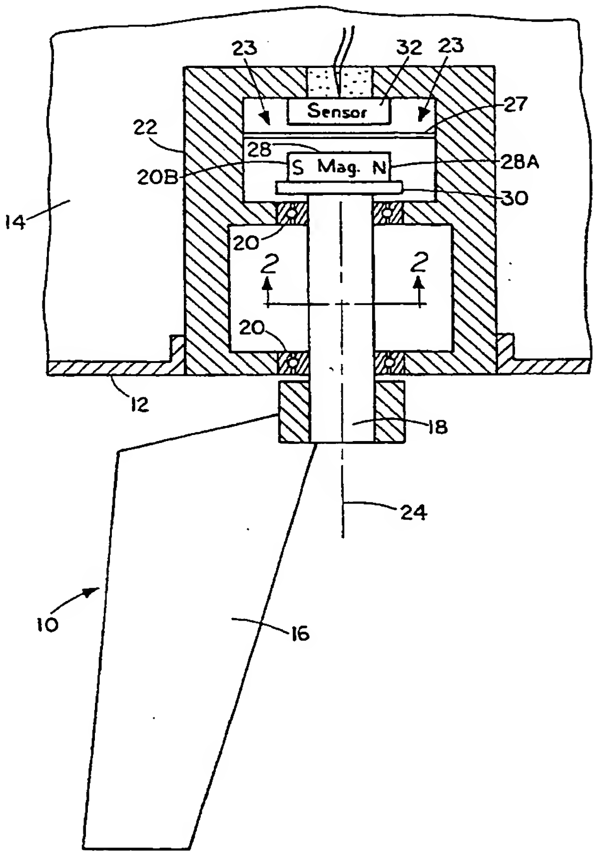
*[Continued on next page]*

(54) Title: MAGNETIC ANGLE OF ATTACK SENSOR




(57) Abstract: An angle of attack sensor (10) has a rotating vane (16) that is sensitive to airflow direction mounted on a shaft (18) that in turn is rotatably mounted on a housing (22). The housing (22) is supported on an aircraft (14), and includes a non contact magnetic sensing assembly (23) for sensing the rotation of the shaft (18) relative to the housing (22). The sensor assembly (23) includes a magnet (28) that mounts on the shaft (18), and a magnetoresistive (MR) sensor (32) that mounts on the housing (22) in a position so that as the shaft (18) rotates the magnetic field from the magnet (28) changes, and this change in magnetic field is sensed and provided as an indication of angle of attack change.

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# INTERNATIONAL SEARCH REPORT

Inte 'ional Application No
PCT/US 01/10956

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 G01P13/02

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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| X | GB 1 247 416 A (THE BENDIX CORPORATION) 22 September 1971 (1971-09-22) page 2, line 5 - line 9 | 1-5,7,8, 10,12 |
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| Y | column 2, line 1 - line 38 | 9,11 |

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 28 November 2001 | 21/12/2001 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Nessmann, C |



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